Original Contribution

Built Environment and 1-Year Change in Weight and Waist Circumference in Middle-Aged and Older Adults

Portland Neighborhood Environment and Health Study

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This study examined neighborhood built environment characteristics (fast-food restaurant density, walkability) and individual eating-out and physical activity behaviors in relation to 1-year change in body weight among adults 50–75 years of age at baseline. The authors surveyed 1,145 residents recruited from 120 neighborhoods in Portland, Oregon. During the 1-year follow-up (2006–2007 to 2007–2008), mean weight increased by 1.72 kg (standard deviation, 4.3) and mean waist circumference increased by 1.76 cm (standard deviation, 5.6). Multilevel analyses revealed that neighborhoods with a high density of fast-food outlets were associated with increases of 1.40 kg in weight ($P < 0.05$) and 2.04 cm in waist circumference ($P < 0.05$) among residents who visited fast-food restaurants frequently. In contrast, high-walkability neighborhoods were associated with decreases of 1.2 kg in weight ($P < 0.05$) and 1.57 cm in waist circumference ($P < 0.05$) among residents who increased their levels of vigorous physical activity during the 1-year assessment period. Findings point to the negative influences of the availability of neighborhood fast-food outlets and individual unhealthy eating behaviors that jointly affect weight gain; however, better neighborhood walkability and increased levels of physical activity are likely to be associated with maintaining a healthy weight over time.

body weight changes; environment; exercise; prospective studies; residence characteristics; urban health

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Editor's note: An invited commentary on this article appears on page 409, and the authors' response is published on page 413.

The obesity epidemic in the US population has become the nation's fastest growing health threat (1, 2). Overweight and obesity are associated with numerous diseases and negative health conditions, including hypertension, osteoarthritis, type 2 diabetes, coronary heart disease, and stroke (3, 4), and the attendant problems have a significant impact on the US health care system (5–7). Fundamentally, obesity is the result of complex interactions among genetic, behavioral, and environmental factors (8). That is, being overweight is associated with not only genetic predisposition and obesity-related individual behaviors but also built environment factors such as location of residence, resources, walkability,

land use, sprawl, and transportation (9–19). Because it is such a critical public health issue, research has begun to focus on the role that the built environment plays in moderating caloric intake and expenditure (20–22).

To date, the vast majority of studies examining the built environment and obesity have used cross-sectional research designs. As a result, relatively little is known about how person and built environment characteristics relate to weight change over time. This study addresses the person and environment interaction question by considering both an obesogenic environment (i.e., fast-food restaurant distribution) and an environment conducive to healthy living (i.e., neighborhood walkability). Current evidence suggests that certain types of urban form, such as sprawl and lack of street connectivity, are associated with the likelihood of being overweight or obese (9–12), whereas high-walkability neighborhoods are associated with a decreased likelihood

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of being obese and a high level of physical activity (12). Furthermore, emerging evidence suggests that built environment factors may act as modifiers of the person-obesity relation (11, 13). Thus, from a public health perspective, understanding how environments promote unhealthy eating and/or encourage physical activity is critical when making urban planning and public health decisions to ameliorate the obesity epidemic.

Building on evidence from prior research (9–13, 15–17, 19), we examined neighborhood-level variables of fast-food restaurant density and walkability as effect modifiers in the relation between individual behavioral indicators (i.e., eating out at fast-food restaurants, engaging in physical activity) and change in body weight and waist circumference in a community sample of adults 50–75 years of age in 2006–2007. We selected this age cohort because the population included immediate pre–baby boom/early–baby boom generations, which will become the major demographic related to health care utilization in the next 20 years. We hypothesized that, in neighborhoods with high densities of fast-food outlets, there would be a positive relation between eating out frequently at local fast-food restaurants and increases in weight and waist circumference. In contrast, it was predicted that, in high-walkability neighborhoods, there would be a negative relation between engaging in physical activity and weight and waist circumference.

MATERIALS AND METHODS

Study design and sample

Study design and subject recruitment procedures for the Portland Neighborhood Environment and Health Study have been described elsewhere (12). Briefly, the study used a prospective, multilevel design (details below) that enabled examination of how the built environment may influence levels of obesity and physical inactivity in a large population of community adults. In 2006–2007, 1,221 individuals aged 50–75 years were recruited from a defined sampling frame of the Portland, Oregon, metropolitan region's urban growth boundary.

The study cohort participated in a baseline health survey (2006–2007) and continues to participate in annual follow-up surveys. Subjects were paid $15–$20 for their participation, plus reimbursement for transportation. Retention at the first follow-up (2007–2008; mean follow-up = 11.5 months) was 94% (n = 1,145) (656 men, 489 women). Of those not included in the current study (n = 76), 41 declined, 8 moved out of the study area, 9 died, and 18 could not be reached to complete the surveys. There were no differences between those included in the current study (n = 1,145) and those who were not (n = 76) from the original cohort (N = 1,221) with respect to gender, age, education, body weight, and waist circumference. However, participants had a higher self-reported health status (mean = 2.44; excellent = 5, poor = 1) than nonparticipants did (mean = 2.16). All participants gave their written informed consent, and the study protocol was approved by the institutional review board of the Oregon Research Institute.

Sampling methods

The primary sampling unit was block groups. The sample was selected by using a stratified, 3-stage, proportional-to-size cluster sample method. The first stage involved the selection of census block groups (used as proxies for neighborhoods). The total number of block groups (N = 789) within the urban growth boundary was first stratified on the basis of neighborhood land-use mix (high, low), socioeconomic status (high, low), and ethnic mix (African American vs. other). This 2-by-2-by-2 stratification matrix resulted in 8 total strata, from which 15 block groups were randomly drawn from each stratum, resulting in 120 block groups (neighborhoods). In the second stage of sampling, individual households within these selected neighborhoods were randomly drawn. Proportional allocation was used in this stage to determine the size of the resident sample in each neighborhood, with numbers varying from 5–8 residents for small population block groups to 9–21 residents for medium-to-large population block groups. In the last stage, one eligible study participant within each selected household was chosen. Inclusion criteria were 1) English speaking, 2) age 50–75 years, 3) no sign of significant mental deficit (23), and 4) able to walk (including cane use). The overall study response was 48%, which reflects the general response rate in survey-based studies (10). There were no major differences between responders and nonresponders with respect to sociodemographic characteristics at either the resident or neighborhood level.

Study procedures and data collection

Participants were initially contacted via telephone interviews, followed by a face-to-face interview either at the research office or at home. Data were collected in the form of 1) anthropometric measures of body weight, height, and waist circumference; 2) responses to survey questionnaires including demographic information, health status, dietary intake, and physical activity measures; and 3) geographic databases and census data. Both resident- and neighborhood-level data at baseline were collected in a series of waves between 2006 and 2007, and follow-up resident-level data were collected between 2007 and 2008. All resident-level data were collected by trained research assistants per established protocols.

Body size measurements

At baseline and follow-up, anthropometric measures of body weight (in pounds; 1 pound = 0.45 kg), height (in inches; 1 inch = 2.54 cm), and waist circumference (in inches) were obtained from the study participants. Weight was measured by using either a balance or a digital scale while participants stood in stocking feet and light clothing. Scales were calibrated annually. Waist circumference was measured with a measuring tape placed at the level of the umbilicus. All measures were converted into metric equivalents prior to data analyses. In the current study, changes in weight (kilograms) and waist circumference (centimeters) were calculated as the difference from baseline to 1-year follow-up.

Physical activity

Behavioral Risk Factor Surveillance System survey questions were used (24) at baseline and follow-up to assess the frequency (number of days) and duration (in minutes) of weekly moderate and vigorous physical activity. Moderate activities were defined as engaging in, for at least 15 minutes at a time, activities such as brisk walking, bicycling, vacuuming, and gardening that led to some increases in breathing or heart rate. Vigorous activities were defined as engaging in, for at least 10 minutes at a time, activities such as running, aerobics, and heavy yard work that produced large increases in breathing or heart rate. Values of physical activity measures were multiplied to provide the total number of minutes of each activity in a usual week (7 days). Change in physical activity (in minutes/week) was calculated by subtracting baseline from 1-year follow-up values, with positive scores indicating increases in physical activity and negative scores indicating decreases in physical activity. The change scores for the 2 levels of activities were then defined categorically (2 levels) as values ≥75th percentile of change (range: 90–770 minutes/week for moderate activities, 15–554 minutes/week for vigorous activities) or below (range: −700 to 0 minutes/week for moderate activities, −650 to 0 minutes/week for vigorous activities).

Eating-out behavior

At each assessment (i.e., baseline, follow-up), participants were asked 2 questions about their weekly visits to local fast-food restaurants: 1) "How often do you eat food from a place like McDonalds, Burger King, KFC, Pizza Hut, or some other fast-food restaurant?" and 2) "How often do you go to buffet-type restaurants?" These items were measured on a 6-point Likert-type scale, with 1 = never, 2 = less than once per week, 3 = 1–2 times a week, 4 = 3–4 times a week, 5 = 5 times a week, and 6 = every day. For the purpose of analysis, a binary score for eating out at fast-food restaurants was created across the 2 assessments. Participants were considered as having made frequent visits if they responded 3 or higher on either question (i.e., 1 = ≥1–2 times/week). Participants were considered as having made no regular visits (i.e., 0 or less than once per week) if they responded 1 or 2 for both questions.

Fast-food restaurants

Commercial business establishment data within the study's geographic area were purchased (www.infousa.com). The data set, dated up to 2006, included names, addresses, and types of fast-food restaurants. Information on food-related outlets was compiled by using proprietary 6-digit extensions to the Standard Industrial Classification codes (581206, 581208, 581222), which included various fast-food chain restaurants or franchises such as McDonald's, Burger King, and Wendy's. The compiled data were then spatially integrated within a geographic information system (ArcView 9.1; ESRI, Redlands, California) by using the existing geographic information system data provided by the Metro Data Resource Center in Portland (www.oregonmetro.gov). All records were successfully geocoded, with 94% matched to the street address. For analysis, the number of fast-food outlets was divided by area in square miles (1 mile = 1.6 km) to obtain a density measure (number of fast-food outlets per square mile) for each of the 120 neighborhoods. The measure was standardized and the resulting scores were further divided into percentiles, with scores ≥75th percentile coded as high-density neighborhoods and those below indicating low-density neighborhoods.

Walkability index

In line with previously published studies (25–27), a walkability index was calculated on the basis of a composite score consisting of land-use mix, street connectivity, public transit stations, and green and open spaces (12). Following the recommendations of Frank et al. (26), scores for these 4 variables were standardized and summed, and the final scores were divided into percentiles, with scores ≥75th percentile coded as high-walkability neighborhoods and scores below indicating low-walkability neighborhoods.

Covariates

Unless noted, measures of covariates were derived from the baseline data. On the basis of prior research on the correlates of obesity (9–12, 15), at the neighborhood level, measures of residential density, median household income, percentage of non-Hispanic black residents, and percentage of Hispanic residents were included. At the resident level, sociodemographic measures of age (1 = 50–64 years, 0 = ≥65 years), gender (1 = female, 0 = male), education (1 = high school diploma or lower, 0 = some college or higher), household income (1 = ≤$29,999, 0 = ≥$30,000), race/ethnicity (1 = non-Hispanic black, 0 = otherwise), tobacco use (1 = current user, 0 = never or no use), employment status (1 = currently employed, 0 = not employed), and health status (5 = excellent, 1 = poor) were included. Also included were the baseline values of body mass index, weight, and waist circumference.

Data analyses

Neighborhood-level (aggregated) descriptive analyses were performed by using analysis of variance to examine mean-level change in weight and waist circumference stratified by density of fast-food restaurants and walkability. Major analyses were conducted by using multilevel modeling methodologies (28). The 2 dependent variables were baseline-to-1-year-follow-up-change scores of body weight and waist circumference. Primary independent variables were density of fast-food restaurants and neighborhood walkability at the neighborhood level, and eating out at fast-food restaurants and change in moderate and vigorous physical activity at the resident level. Confounding variables included neighborhood-level covariates of residential density, median household income, percentage of non-Hispanic black residents, and percentage of Hispanic residents and resident-level covariates of age, gender, education, race/ethnicity, household income, health status, smoking, and body mass index.

Table 1. Baseline Sample Characteristics of Study Participants and Neighborhoods by Neighborhood Walkability, Portland Neighborhood Environment and Health Study, 2006/2007

Characteristics	High Walkability		Low Walkability		Whole Sample	
	No.	%	No.	%	No.	%
Resident level (baseline: 2006–2007; $n = 1,145$)[a]						
Age, years (mean (SD))	63 (7)		61 (7)		62 (7)	
Gender: male	185	56	471	58	656	57
Race: white	304	92	752	93	1,056	92
Annual household income: $\geq$\$30,000	235	70	605	74	840	73
Education: >12 years	263	79	626	77	889	78
Body mass index[b] (mean (SD))	29.17 (6.7)		29 (6.4)		29.08 (6.5)	
Health status: good to excellent	279	84	684	84	963	84
Visits to fast-food restaurants	66	20	175	22	241	21
Neighborhood level (baseline: 2006; $n = 120$)[c]						
Average population size	2,659	—[d]	1,664	—	1,931	—
Residential density: persons per square mile,[e] mean	5,874	—	6,097	—	6,034	—
Residents aged $\geq$50 years	24,939	28	38,971	28	63,910	28
Neighborhood median family income, $	38,314	—	50,645	—	47,152	—

Abbreviation: SD, standard deviation.

[a] Refer to the Materials and Methods section of the text for inclusion criteria; numbers of participants by level of walkability: high walkability = 332, low walkability = 813.

[b] Calculated as weight (kg)/height (m)^2.

[c] Numbers of neighborhoods by level of walkability: high walkability = 34, low walkability = 86.

[d] Not applicable.

[e] One mile = 1.6 km.

To justify multilevel modeling, we examined the neighborhood effects on the outcome measures by calculating the intraclass (intra-neighborhood) correlation, defined as a ratio of between-neighborhood variability/(between-neighborhood variability + within-neighborhood variability). A 2-level hierarchical linear model was then specified for each dependent variable, and modeling was conducted in 4 steps. In step 1, we estimated an unconditional model in which no between- or within-neighborhood-level variables were specified. In step 2, we estimated a random-coefficient model (main-effect model) in which only between-neighborhood-level variables were specified, whereas, in step 3, we estimated a similar model in which only within-neighborhood-level variables were specified. In step 4, we built on the previous models by estimating a model inclusive of both level-specific main and cross-level interaction effects.

To model cross-level interaction effects, we added neighborhood-level variables of density of fast-food restaurants and walkability as predictors of resident-level variables of visits to fast-food restaurants and physical activity to predict whether the 2 neighborhood-level variables account for any between-neighborhood-level variation in change in weight and waist circumference over time. The 3 a priori cross-level interaction terms in the model were 1) density of fast-food outlets by eating out at fast-food restaurants, 2) neighborhood walkability by change in moderate physical activity, and 3) neighborhood walkability by change in vig-

orous physical activity. Final results of this model are summarized and interpreted in the Results section. All statistical tests were 2-sided. Model testing was conducted by using the Hierarchical Linear and Nonlinear Modeling software (29).

RESULTS

Baseline participant and neighborhood characteristics are presented in Table 1. The study population (mean age = 62 years) was mostly men (57%) and white (92%), with an average body mass index above normal (i.e., $\geq$25 kg/m^2; mean = 29.08). Table 2 displays the association of baseline neighborhood-level density of fast-food restaurants (high vs. low) by walkability (high vs. low) with weight and waist circumference. As shown, the baseline weight and waist circumference values were the lowest for neighborhoods with high densities of fast-food restaurants and high walkability. In contrast, these baseline values were the highest for neighborhoods with high densities of fast-food restaurants and low walkability.

During the 1-year follow-up (2006–2007 to 2007–2008), mean weight increased by 1.72 kg (standard deviation, 4.3) and mean waist circumference increased by 1.76 cm (standard deviation, 5.6) for the overall sample. Table 3 presents change scores from baseline, separated by high and low densities of fast-food restaurants and walkability at the neighborhood level, and residents' health behaviors of visits

Table 2. Study Participants' ($N = 1,145$) Measures of Weight and Waist Circumference at Baseline (2006/2007) by Neighborhood Walkability and Density of Fast-Food Restaurants, Portland Neighborhood Environment and Health Study, 2006–2008

| Neighborhood Walkability (High vs. Low)[a] | Density of Fast-Food Restaurants (High vs. Low)[b] | | | |
| | Weight, kg | | Waist Circumference, cm | |
	High	Low	High	Low
High	82.83	84.08	96.09	98.54
Low	88.46	85.43	100.36	98.62

[a] Defined by percentile scores: high walkability = ≥75th percentile, low walkability = <75th percentile; high = 34 neighborhoods, low = 86 neighborhoods.

[b] Defined by percentile scores: high density = ≥75th percentile, low density = <75th percentile; high = 30 neighborhoods, low = 90 neighborhoods.

to fast-food restaurants and change in physical activity (moderate, vigorous) at the resident level. Significant between-group (i.e., fast-food density by visits to fast-food restaurants, walkability by change in physical activity) differences in change in weight and waist circumference were observed ($P < 0.05$). Results show 1) for high-density fast-food neighborhoods, a significant increase in weight and waist circumference over time in those residents who made

weekly visits to fast-food restaurants (3.00 kg in weight, 4.47 cm in waist circumference); and 2) for high-walkability neighborhoods, the least increase for residents who increased their levels of physical activity (for moderate and vigorous physical activity: 0.86 kg and 0.19 kg in weight and 1.07 cm and 0.41 cm in waist circumference, respectively).

With respect to inter-neighborhood variability, the results indicate intraclass correlations of 0.18 and 0.19 for the outcome measure of weight at baseline and at 1-year follow-up, respectively, and of 0.15 and 0.18 in waist circumference at baseline and at 1-year follow-up, respectively. These coefficients indicate that about 18%–19% of the variation in weight and 15%–18% in waist circumference was due to between-neighborhood differences. The magnitude of these coefficients indicates a reasonable amount of variation occurring at the neighborhood level, providing justification for multilevel analysis to examine between-neighborhoods-level variation in change in the response variables.

Major results from multilevel analyses of change in outcome measures are presented in Table 4. Visits to fast-food restaurants and vigorous physical activity were the only 2 resident-level variables that predicted change in body weight and waist circumference. With respect to the study hypotheses, 2 of the 3 interaction terms were statistically significant ($P < 0.05$). Results showed that, adjusted for neighborhood- and resident-level sociodemographic characteristics, 1) a high density of fast-food outlets was associated

Table 3. Study Participants' ($N = 1,145$) Baseline to 1-Year Change in Weight and Waist Circumference by Resident- and Neighborhood-Level Characteristics, Portland Neighborhood Environment and Health Study, 2006/2007–2007/2008

| | No. of Residents | Weight, kg | | Waist Circumference, cm | |
		High	Low	High	Low
		Density of fast-food restaurants[a]			
Visits to fast-food restaurants					
≥1–2 times	357	3.00 (4.98)[b]	2.24 (3.85)	4.47 (5.75)[b]	2.22 (5.42)
0	788	0.85 (4.25)	1.57 (4.31)	1.15 (4.99)	1.30 (5.70)
		Neighborhood walkability[c]			
Moderate physical activity					
Change	314	0.86 (4.59)[d]	1.60 (5.35)	1.07 (5.12)[d]	1.49 (6.02)
No change	831	2.08 (3.50)	1.74 (4.08)	2.62 (5.70)	1.60 (5.44)
Vigorous physical activity					
Change	333	0.19 (4.74)[e]	1.03 (5.32)	0.41 (5.48)[e]	0.96 (5.36)
No change	812	2.47 (3.13)	1.97 (4.06)	3.30 (5.45)	1.81 (5.68)

[a] High = 30 neighborhoods, low = 90 neighborhoods.

[b] Significantly different from the other 3 groups, $P < 0.05$.

[c] High = 34 neighborhoods, low = 86 neighborhoods.

[d] Significantly different from the High-walkability neighborhoods with No change group, $P < 0.05$.

[e] Significantly different from the High-walkability neighborhoods with No change group and the Low-walkability neighborhoods with No change group, $P < 0.05$.

Table 4. Multilevel Analysis of Change in Weight and Waist Circumference Over a 1-Year Period as a Function of the Interaction Between Visits to Fast-Food Restaurants and Density of Fast-Food Outlets and Between Change in Physical Activity and Neighborhood Walkability,[a] Portland Neighborhood Environment and Health Study, 2006–2008

	Weight, kg			Waist Circumference, cm		
	β	SE[b]	P value	β	SE	P value
Variable (level-specific main effect)						
Visits to fast-food restaurants[c]	0.65	0.32	<0.05	1.06	0.41	<0.05
Change in moderate physical activity[d]	−0.23	0.29	0.41	−0.37	0.37	0.32
Change in vigorous physical activity[e]	−0.90	0.33	<0.05	−0.68	0.43	0.11
Neighborhood density of fast-food restaurants[f]	−0.66	0.37	0.07	−0.37	0.52	0.48
Neighborhood walkability[g]	0.52	0.35	0.13	1.10	0.52	0.67
Variable (cross-level interaction term)						
Visits to fast-food restaurants by neighborhood density of fast-food restaurants	1.40	0.61	<0.05	2.06	0.41	<0.05
Change in vigorous physical activity by neighborhood walkability	−1.20	0.59	<0.05	−1.57	0.77	<0.05

[a] Analyses were adjusted for neighborhood- and resident-level baseline sociodemographic characteristics, including age, gender, education, household income, race/ethnicity, smoking, health status, body mass index, weight, and waist circumference at the resident level and for residential density, median household income, percentage of non-Hispanic black residents, and percentage of Hispanic residents at the neighborhood level.

[b] Standard error (SE) of the estimate.

[c] Resident-level variable—measured on a 2-point scale: 1 = 1–2 times or more, 0 = never or less than once per week.

[d] Resident-level variable—defined as values ≥75th percentile of change (90 minutes/week) (coded as 1) or below (<90 minutes/week) (coded as 0).

[e] Resident-level variable—defined as values ≥75th percentile of change (15 minutes/week) (coded as 1) or below (<15 minutes/week) (coded as 0).

[f] Neighborhood-level variable—defined by percentile scores: high density = ≥75th percentile, low density = <75th percentile. Refer to the Materials and Methods section of the text for more information.

[g] Neighborhood-level variable—defined by percentile scores: high walkability = ≥75th percentile, low walkability = <75th percentile. Refer to the Materials and Methods section of the text for more information.

with an increase of 1.40 kg (3.09 pounds) in weight and 2.06 cm (0.81 inches) in waist circumference among residents who frequently ate at fast-food restaurants; and 2) high walkability was associated with a decrease of 1.2 kg (2.65 pounds) in weight and 1.57 cm (0.62 inches) in waist circumference among residents who increased their levels of vigorous physical activity.

DISCUSSION

Findings from this study suggest an important interplay between the built environment and individual lifestyle in terms of change in adiposity. The significant interaction effects of neighborhood-individual characteristics indicate that residents living in neighborhoods with a high density of fast-food outlets who also visit these outlets weekly increase their weight and waist circumference over time. This finding is generally consistent with other studies involving cross-sectional data that show a positive association between obesogenic environments and overweight or obesity (12, 13, 15).

Our findings also show a significant interaction effect of vigorous physical activity by neighborhood walkability on 1-year change in body composition, indicating that living in high-walkability neighborhoods and engaging in vigorous levels of physical activity are associated with decreases in both weight and waist circumference. In contrast, we found no evidence that, for high-walkability neighborhoods, engaging in moderate physical activity reduces weight over time. This finding may suggest either that it is insufficient to engage in moderate levels of physical activity to change body weight or that a 1-year lag is too brief to detect any differences.

Although difficult to compare directly with other studies because of differences in designs and methodologies, our findings are generally congruent with those using cross-sectional data in that neighborhood walkability contributes to walking of various types (12, 25, 27, 30, 31) but may not be necessarily related to weight change (25, 32). In this regard, the current study adds to the literature by considering effect modification of neighborhood walkability between physical activity and change in weight and providing evidence that, for high-walkability neighborhoods, engaging in vigorous physical activity helps to maintain or reduce weight over time. It is not known, however, whether people who are more physically active tend to choose to live in high-walkability

neighborhoods or vice versa, indicating that additional study of this relation is warranted.

Study limitations

This study is limited in that the study population included 2 age cohorts—middle-aged and older adults. It is possible that, compared with younger adults, older adults in the study population may experience more life-related transitions, such as from employment to retirement, with an attendant drop in income. Therefore, although we controlled for employment status, personal income, and age in our analyses, weight status may be influenced by factors not fully accounted for in the current study. Second, although we were unaware of any ongoing community-based interventions, the observed change (e.g., decreases in weight and waist circumference among those physically active and living in high-walkability neighborhoods) may have been affected by increased local health promotion efforts or awareness of health-related issues that may have impacted residents' weight status or physical activity. Third, we did not consider change in built environment attributes that were minimally observable given the 1-year observation period. With a longer follow-up period, future studies may determine whether change or variation in the built environment is related to change in weight.

Future research and public health implications

Future research efforts should extend the longitudinal, multilevel framework used in this study to investigate more complex person-to-environment influences. For example, in the current study, we found that significant influences of both neighborhood fast-food density and walkability moderate the relation between individuals' lifestyles (i.e., eating habits, physical activity) and change in body weight and waist circumference. Significant implications may arise in public health and urban planning if future studies begin to look into specific roles that neighborhood walkability plays in ameliorating the influence of fast-food density/restaurant visits on change in body composition. Similarly, it is plausible that more convenient access to unhealthy fast food, coupled with decreased levels of physical activity, may increase weight. Therefore, the role of physical activity in the context of high- and low-walkability neighborhoods should be examined to better understand its unique influence on built environment factors, which, directly and indirectly, affect overweight and obesity in adults. This information can guide public health investigations to slow the pace of the growing epidemic of obesity.

In the United States, more than 30% of adults are obese and approximately 65% are considered overweight, and the prevalence of obesity continues to increase (33–35). Consensus is growing that the built environment impacts health (18, 21, 22). From a public health perspective, a number of implications from this study are worth noting. First, weight status changes in middle-aged and older adults, and these change are influenced, at least in part, by built environment characteristics such as density of fast-food restaurants and neighborhood walkability, in conjunction with individual

lifestyle factors (i.e., eating habits, levels of physical activity). Findings thus suggest that intervention and prevention efforts to reduce overweight or obesity by simply focusing on encouraging individuals to change their unhealthy eating habits may be insufficient. Additional effort is needed to improve the built environment to promote healthy weight status. Second, it is increasingly evident that public health professionals need to develop more effective strategies to improve food-environment conditions by better regulating fast-food businesses or increasing consumer awareness of the nutritional characteristics of fast food. Lastly, and perhaps most importantly, the findings suggest the potential value of promoting neighborhood walkability to increase physical activity to combat the negative influences of fast-food density. In this respect, urban planners need to promote key features of neighborhood walkability, such as mixed-land use, interconnecting streets, convenient transit locations, and compact but walkable communities that support healthy lifestyle changes.

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